CORE
Metadata, citation and similar papers at core.ac.uk
Provided by Elsevier - Publisher Connector

ANALYSIS OF RAILWAY USER TRAVEL BEHAVIOUR PATTERNS OF DIFFERENT AGE GROUPS

Takamasa AKIYAMA
Professor
Department of Civil, Environmental and Applied System Engineering
Faculty of Environmental and Urban Engineering
Kansai University
Osaka, Japan

Masashi OKUSHIMA
Associate Professor
Department of Ecosystem Engineering
Graduate School of Advanced Technology and Science
The University of Tokushima
Tokushima, Japan

(Received March 2, 2009)

In recent years, there have been requirments for a transport environment that will foster the development of safe, comfortable townships. The study of urban activities amid an aging society and effective use of public transport modes in addressing environmental problems have become particularly important issues. This study analyzes travel behaviour patterns of varying age groups using urban railways in order to examine the relationship between urban public transport use and urban activities. Specifically, it analyzes the composition of urban activity and travel behaviour patterns among urban railway users in the Keihanshin (Kyoto-Osaka-Kobe) metropolitan area. This paper looks at urban activities within aging societies and identifies the differences in travel behaviour of railway users by separating them into young, middle aged and senior citizen age groups. Analysis makes particular use of the Railway Station Database, which is a compilation of existing studies into attributes of railway stations and their surroundings, and results of person trip surveys. Rail use behaviour characteristics have been sorted by age group because mobility via urban railway systems is varied by age group. As a result, differences in railway usage patterns (travel objectives, distance and time, and number of transfers, etc.) have been identified and so too have differences in urban activity patterns related to free activities (shopping, recreation). Furthermore, the study developed a travel behaviour pattern estimation model which is capable of categorizing specific transport behaviour patterns and estimating rail users and transport behaviour patterns from the relationship with areas surrounding railway stations to ensure future mobility by public transport for older age groups. The results make it possible to put forward proposals for urban rail services that will facilitate urban activities for the different age groups. Eventually, it will be possible to understand the effect of rail transport as public transport mobility on urban activities of different age groups.

Key Words: Aging society with a falling birthrate, Urban activity, Travel behaviour pattern, Urban railway demand, Town development

1. INTRODUCTION

In recent years, there have been requirments for a transport environment that will foster comfortable and safe town development. Studies on urban activities in aging societies with falling birthrates and effective use of public transport modes in addressing environmental problems have become particularly important issues. Public transport is of great importance, especially from the perspective of town development and urban transport, and for securing mobility for the young and advanced age groups. The Transportation Accessibility Law was introduced in 2000 to facilitate access by the elderly and the disabled, etc. to public transport. This brought about modification of facilities to comply with the law at railway stations with 5,000 users a day or more. Reviews of urban frameworks were also deemed necessary in progressively aging societies. Thus, the New Transportation Accessibility Law was introduced in 2006 aimed at expanding barrier-free features of public transport to universal design in cities. According to the background, this study focuses on the urban railway aspect of public transport and analyzes travel behaviour patterns by age group in reviewing the role of urban railway in an aging society with a falling birthrate. Railway use by those commuting to work and school is on the decline[1,2] and there is a great need to encourage the use of railways based on the urban activities of respective age groups. This paper analyzes the travel behaviour of railway users by age group from the perspective of railway stations and town planning. In addition to summarizing railway trip characteristics, it also analyzes the connection between railway use and urban activities by age group. Thus, it examines urban railway usage by respective age groups. The trend towards an aging population and declining birthrates in recent years must be taken into account in town planning projects aimed at revitalizing city centres. For this reason, this study seeks to identify basic differences in travel behaviour by way of an age group-specific analysis of travel behaviour.

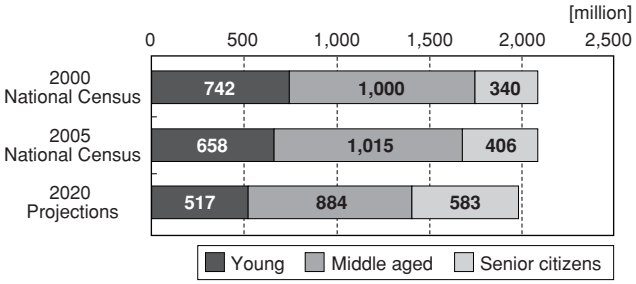

Fig. 1 Population by age group of the Keihanshin metropolitan area

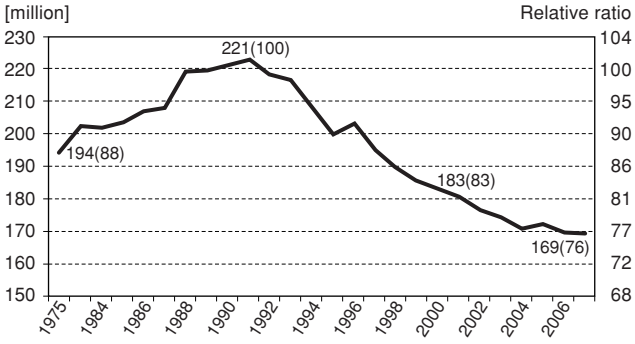

Fig. 2 Changes in the average daily volume of passengers carried on urban railways in the Keihanshin metropolitan areas (Hankyu)

In this paper, "young" shall refer to rail users under the age of 30, "middle aged" to those aged between 30 and 64, and "senior citizens" to those aged 65 or over. Following to this definition, Figure 1 shows the secular change in population by age group (including estimated figures) of the Keihanshin (Kyoto, Osaka, Kobe) metropolitan areas. According to the chart, in 2005, senior citizens accounted for 19.5% of the population in the Keihanshin metropolitan areas (encompassing six prefectures). This figure is more or less the same as the national average of 20.2%.

In 2005, the senior-citizen population of the Keihanshin metropolitan areas grew by 660,000 over 2000. Over the same period, the young age group population fell by 840,000. Thus, there is a notable acceleration in demographic aging. It is estimated that by 2020, the senior-citizen population will increase by 1,780,000 and will exceed the young age group population[3]. For these reasons, while the core of urban activities at the moment consists of young and middle aged groups, this paper will examine urban railway demand from the standpoint of stimulating public transport usage by specific age groups encompassing the young and senior citizen age groups which represent the potential of future urban activities.

First of all, we will look at the secular change in urban railway demand in the Keihanshin metropolitan areas. Figure 2 shows the temporal changes in the average daily volume of passengers carried on urban railway in the Keihanshin metropolitan areas, taking Hankyu Railway as an example[4]. The index value shown on the side is for the purpose of annual comparison. The average daily volume of passengers for 1990 (2,210,420) has been set at the value of 100. According to this graph, the volume of passengers carried on urban railways (Hankyu Railway) peaked in 1990 and has continued to decline gradually to this day. The same downward trend has been demonstrated by other urban railway companies in the Keihanshin metropolitan areas. In fact, a downward trend in urban railway use is notable throughout all Keihanshin metropolitan areas. This trend is largely believed to be caused by the falling birthrate and the aging population as well as the advancement in motorization. It can therefore be deduced that time series changes in age composition and changes in lifestyles exert changes to urban transport demand. Furthermore, there is a significant drop in the ratio of rail use as seen from the fact that the basic unit for trips on urban railways (Hankyu) in proportion to the population of the Keihanshin metropolitan areas was 0.400 trips/person (2,210,420/5,524,463) in 1990 but fell to 0.330 trips/person (1,827,422/5,541,905) in 2000.

Figure 3 shows the temporal changes in the pro-

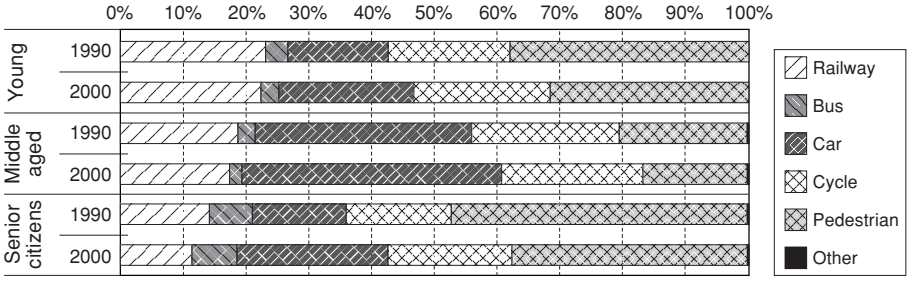

Fig. 3 Changes in transport mode share by age group

portion of transport mode usage by age group. It calculates the share of traffic carried by respective transport modes according to age group in 1990 and in 2000 in the Keihanshin metropolitan areas, based on the results of person trip surveys in the Keihanshin metropolitan areas.

As a general trend, there is an increase in car use and a decrease in pedestrian traffic in all age groups. The decline in pedestrian traffic owing to increased motorization has robbed city areas of their vitality. While the use of cars for transport is on the increase among senior citizens, around 40% still travel by foot. Therefore, faced with an aging population, pedestrian traffic by senior citizens will be an important item improving navigability in cities. Also, looking at the temporal changes in public transport use, the decline in bus use is relatively small whereas that of rail use is significant. From this standpoint, it is necessary as well to examine changes in urban railway demand from the perspective of temporal changes in age composition.

2. ANALYSIS OF AGE GROUP-SPECIFIC RAILWAY USAGE CHARACTERISTICS

Transport related to urban railways is comprised of transport behaviour of passengers boarding and alighting at stations, and urban activities. The fundamental data for this study is taken from the Railway Station Database for the Keihanshin metropolitan areas compiled from existing study material[5,6]. To facilitate a statistical analysis of the relationship between railway stations and town planning, the database provides information on (1) regional hub railway stations that handle over 20,000 passengers (279 stations), and (2) stations that handle less than 20,000 passengers but which are being survey as by railway operators as having capacity for improvement (51 stations)[7]. Based on this criterion, the database is made up of a total of 330 stations out of 1,279 stations throughout the Keihanshin metropolitan areas. This Railway Station Database holds 3 types of data: (1) Basic characteristics of railway station (164 items from data possessed by the office as of September 2005); (2) Travel behaviour characteristics associated with railway stations (126 items from the 4th Keihanshin metropolitan area person trip survey in 2000); and (3) Grid square statistics of areas around railway stations (132 items from 2000 Census data, 2001 Establishment and Enterprise Census data and 2002 Commercial Statistics data)[8].

Grid square data of areas around the railway stations is extracted for the 330 stations in the Railway Station Database above and an estimation model of the number of passengers at the stations is compiled for each age group. Therefore, the paper extracts railway station services and factors in the surrounding region associated with railway use for each age group and clarifies their causal relationship. In practical terms, this involves multiple regression analysis using the number of passengers by age group as a dependent variable. 16 factors associated with urban railway demand—(1) - (16) in Table 1,

Table 1 Estimation result for the number of passengers by age group at urban railway stations

Factor	Young		Middle aged		Senior citizens	
	θ	t value	θ	t value	θ	t value
Constant	8690.898	3.108 *	14053.890	3.576 *	608.356	1.116
(2) Barrier free improvements	−148.868	0.392	−300.021	0.558	30.388	2.093 *
(5) Bus systems	288.675	5.546 *	435.080	5.902 *	64.967	6.142 *
(7) Total industrial plants	−1.747	2.506 *	−0.235	0.239	−0.316	2.280 *
(8) Distance to terminal station	−78.699	2.085 *	−123.809	2.323 *	−15.568	2.032 *
(9) Schools	651.832	3.239 *	530.981	1.866	76.897	1.874
(13) Convenience stores	458.148	2.088 *	856.277	2.757 *	37.191	0.883
(16) Banks	634.479	6.106 *	701.262	4.772 *	128.556	6.071 *
Multiple correlation coefficient	0.578		0.672		0.652	
Determination coefficient	0.335		0.452		0.426	
RMSE	8,706		11,778		1,769	

Factors (1) Population by age group, (2) Barrier free improvements, (3) Total retail area, (4) No. of cars owned, (5) Bus systems, (6) Dummy limited express stops, (7) Total industrial plants, (8) Distance to terminal station, (9) Schools, (10) Cultural facilities, (11) Places of worship, (12) Tourism facilities, (13) Convenience stores, (14) Hospitals, clinics, (15) Parks, open spaces, (16) Banks

*Significant at 5%

such as population by age group, barrier-free development index score and retail shop sales floor area, are used as independent variables. Development status of the railway station is presented using indicators. For instance, with factor (2) Barrier-free Facility Development, the barrier free facilities at the station are scored on a scale of 1 to 4 and other indicators include (5) No. of Bus Services (no. of routes) and (6) Dummy limited express stops (3 types of station). At the same time the number of respective facilities ranging from schools (9) to banks (16) within a grid square around the station (1 km × 1 km) is also used as an indicator.

In this way, this model is used to estimate the number of passengers by age group at each railway station[9].

The estimation result of the multiple regression analysis is shown in Table 1. Of the 16 factors in all, 7 factors were found to be insignificant at a significance level of 5% and 2 factors were seemed to be short on validity from sign conditions. Therefore, these factors have been eliminated and only the significant factors are shown in Table 1.

From Table 1, we can see that "Barrier-free Improvements" is a significant factor in estimating senior-citizen users. That is to say, there is stronger causal relationship between barrier-free improvements and senior-citizen users than with young and middle aged groups. On the other hand, "Convenience Stores", which offer quick daily side trips (shopping), is of significance only in estimating middle aged passenger numbers.

The study above has helped to sort out the main factors affecting urban railway use for each age group and have clarified the basic demand structure for urban railways in the respective age groups. Next, let us consider the applicability of the model in estimating the number of passengers at railway stations. The age-group specific estimation models each have a multiple correlation coefficient of around 0.6 which is a relatively sound estimation result. The estimated and actual values for each age group are shown in Figure 4 - Figure 6.

The graphs indicate that the estimations are generally valid for all age groups but there is a large margin of error in the estimations when there is a large number of passengers. Therefore, there is a possibility that the estimation values for the number of passengers at individual stations are off by quite a margin. But the model enables an estimation of the relative trend in urban railway demand in general.

Next, let us look at the relative urban railway usage characteristics of each age group statistically. Figure 7 shows the ratio of people who go out in the Keihanshin metropolitan areas by age group. The ratio is largest for

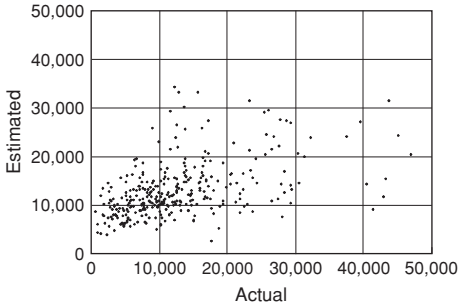

Fig. 4 Estimation result for the number of young passengers

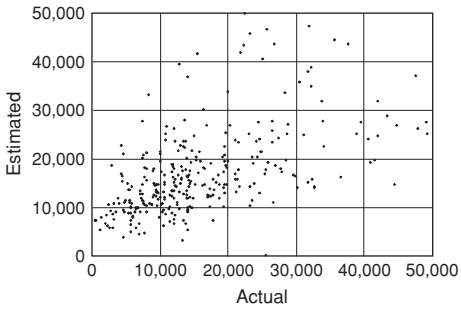

Fig. 5 Estimation result for the number of middle aged passengers

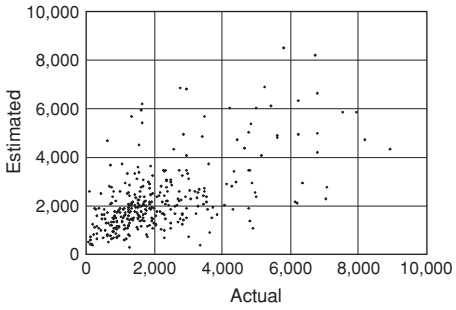

Fig. 6 Estimation result for the number of senior-citizen passengers

the young followed by the middle aged and senior-citizen age groups in descending order. The ratio of people who go out in the senior-citizen age group is relatively low compared to the young and middle aged group who go out for commuting purposes. Moreover, the figure drops to 42% for the latter-stage elderly sector (aged 75 or over) of the senior-citizen age group, indicating that the ratio falls with age.

Due to the above, as shown in Figure 8, the number of railway trips made by senior citizens only account for approximately 7% of the total. This is believed to be because commuting presently accounts for a large propor-

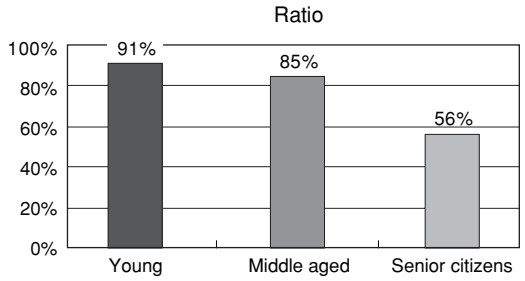

Fig. 7 Ratio of people who go out by age group

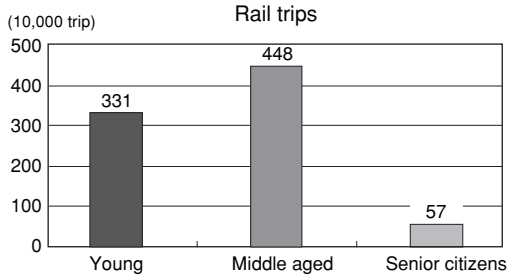

Fig. 8 No. of railway trips by age group

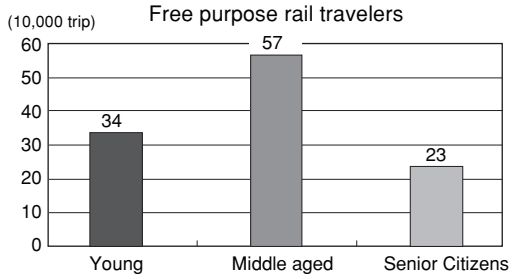

Fig. 9 No. of free-purpose trips by age group

tion of the rail demand. However, since commuting trips have little elasticity in demand, they are not ideal for a study aimed at promoting use of public transport. Rail use by senior citizens is low when compared to the component ratio of the senior-citizen population (16.3%) in the Keihanshin metropolitan areas (2000). It is presumed that there is potential for urban activity among senior citizens.

Railway trips made for free activities (shopping, recreation, leisure) are tallied in Figure 9. In this case, the ratio of trips made by senior citizens is about 25%. We can see that this is a large proportion of the trips for all purposes by age group shown in Figure 8. Figure 10 shows the basic generation unit per person for free-purpose trips by rail for each age group. The basic urban railway use unit for free-purpose trips is approximately the same for the young and middle aged groups. Meanwhile, the basic unit for senior citizens is comparatively

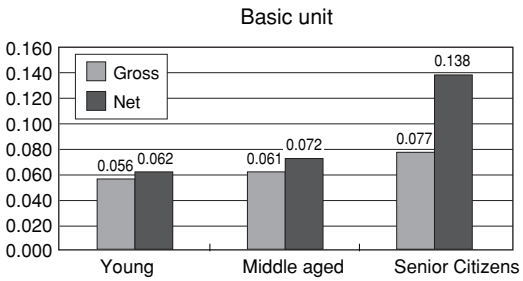

Fig. 10 Free-purpose trip units by age group

Table 2 Statistical indicator for railway use by age group

	Young	Middle aged	Senior citizens
Avg. no. of transfers	0.355	0.374	0.269
Avg. rail use distance (km)	16.8	16.4	13.5
Avg. rail user time spent shopping (minutes)	43	29	46
Avg. rail user time spent on recreation (minutes)	50	47	56

larger. Furthermore, in the case of senior citizens, there is a big difference between the gross trip unit and the net trip unit indicating a significant difference in the travel behaviour of those who go out and those who do not. In other words, it can be assumed that an increase in outings by senior citizens will directly generate more free activity.

Let us next look at the differences in travel behaviour by age group including rail trips. Table 2 shows the average characteristics of rail trips by age group. The average number of transfers on rail trips for the senior-citizen age group is low. Whereas young and middle aged groups used predetermined routes for commuting and for business, senior citizens tended to choose routes with the least number of transfers to the destination and travel for free activities. Furthermore, the average rail travel distance for the young and middle aged groups were about the same while that for senior citizens was relatively short (13.5km) with approximately 20% of the trips being short-distance (around 3km) rides. It can therefore be deduced that senior citizens tend to select urban activity in relatively nearby locations. A breakdown of the free activities reveals that senior citizens spent the longest time with respect to average duration for shopping activities (46 mins) while young people also spent a comparatively long time on shopping (43 mins). With regards recreational activities, there was no great difference in the average duration (activity time) but the longest time was

spent by senior citizens (56 mins).

The above analysis results indicates that senior-citizen travel behaviour differs somewhat to that of young and middle aged groups. (1) Since only a small number commute, the ratio of people who go out among senior citizens is low. Therefore, railway use per person is less than that of young and middle aged groups. (2) A large proportion of senior citizens use rail for free activity (shopping, recreation, etc.). Hence, the railway use unit for free-purpose trips is high. (3) Senior citizens make few transfers and many use the railway for short-distance trips. They spend a relatively long time on free activity.

This data on differences in travel behaviour by age group is mainly that of rail users in the Keihanshin metropolitan areas. Travel behaviour is thought to be dependent on spatial composition of urban transportation. There are thought to be differences in travel behaviour between major metropolitan areas where urban railway system form the main mode of public transport and highly motorized regional cities that are dependent on car travel. Therefore, the same type age group-specific travel behaviour is thought to exist in cities within major metropolitan areas where a rail network has been established to some degree. In such cities, this data can be used as reference for railway station and town development based on age group-specific urban activities. In the local city areas, however, it would be necessary to conduct a travel behaviour analysis that centres on car use within an aging society.

3. ANALYSIS OF TRAVEL BEHAVIOUR PATTERNS BY AGE GROUP

This section examines the connection between railway use and urban activities by age group, particularly focusing on railway usage patterns supporting free activities (shopping, recreation, etc.) in order to identify the relationship between urban railway and the surrounding region (town). In accordance with the trip purpose categorization prescribed for person trip surveys, free-purpose activities that correspond to shopping and recreation shall be referred to as "free activities".

In order to define the travel behaviour at the station and in the surrounding area, it is assumed that a residential zone station is used for the home-based pattern (HB type) and a workplace zone station for the office-based pattern (OB type). For example, in the case of the traveler in Figure 11, Station A would entail HB type movement, whereas Station B would entail OB type movement. Furthermore, "visiting type" travel behaviour pattern is defined as follows: A travel behaviour pattern whereby the residence (HB) and the workplace (OB) of the traveler does not exist in the area around the station and the traveler uses the railway from a different area to perform urban activities in the locality of the station in focus.

According to these definitions, travel behaviour patterns are categorized into 3 types based on the relationship between the area around the station and the point of origin of the traveler. This study also looks at whether free activity took place from the perspective of relationship between commercial activities and the area in focus. Accordingly, 6 types of travel behaviour patterns can be established.

Figure 12 is the result of the 4th Keihanshin metropolitan area person trip survey tallied in traveler units, showing travel behaviour patterns of the Keihanshin railway users by age group. From this chart, we can see that the composition ratios of travel behaviour patterns for the young and middle aged groups are similar. There is a high

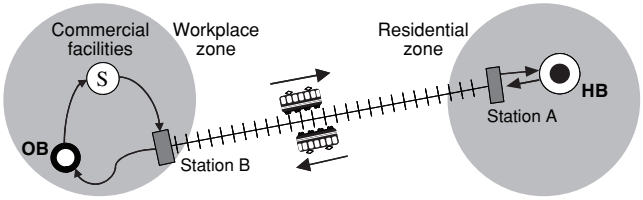

Fig. 11 An example of a railway use travel behaviour pattern

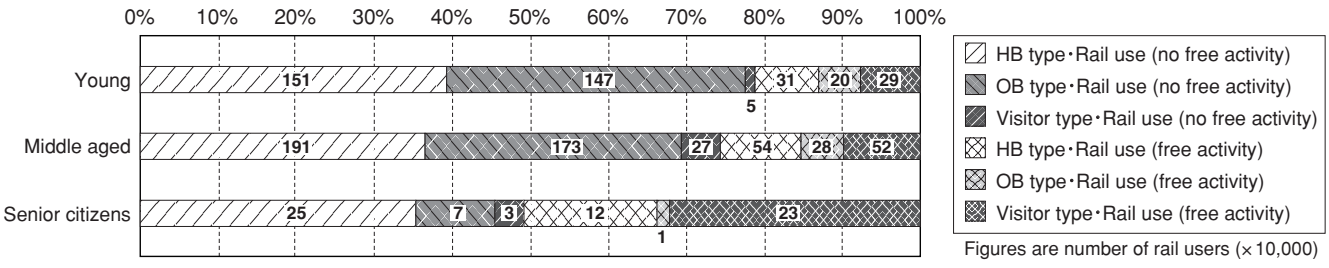

Fig. 12 Travel behaviour patterns in the Keihanshin metropolitan areas by age group

proportion of OB type travelers because there are many commuters. We can also see that round-trip type urban activities relating to HB and OB take up a relatively high proportion of free activities. On the other hand, the proportion of "visiting type free activities" is high among senior citizens compared to the young and middle aged groups, while the proportion of "OB type railway station use (for work)" is low. In other words, travel behaviour mainly to do with free activities represent a large proportion of rail use in the case of the senior-citizen age group. From these results, we can say that with regards the young and middle aged groups, free activities often accompany commuting or business activities, but with regards senior citizens, travel behaviour patterns involving visiting type free activities are relatively common.

Figure 13 illustrates this travel behaviour pattern categorization for the senior-citizen age group in the Keihanshin metropolitan areas. The most commonly found travel behaviour pattern is the HB type (without free activities) which represents movement to a different area using railway. In this case there are no round trips taken around the station. However, since there are multiple records of visiting type and HB type travel behaviour patterns that include free activities, it is realized that senior citizens do engage in free activities in the area around the station when using railway.

Next, let us think about the future travel behaviour pattern composition of the Keihanshin metropolitan areas. Figure 14 shows the number of railway users in 2020 estimated from actual values for 2000 based on the projected population for each age group. Due to further aging in the population, the number of free activities and the number of visiting type travel behaviours of the young and senior-citizen age groups will be reversed. We can see that railway use by senior citizens will take on greater significance in the future.

The following age group-specific travel behaviour patterns were estimated by dividing the 6 types of travel behaviour patterns above into HB, OB and visiting type categories for each age group. Since the estimation is based on the assumption that each factor interacts with one another in complex ways, in this study, the travel behaviour pattern for each age group is estimated from the attributes of the area around the railway station. A neural network (NN) model is used for modeling the complex correlations of the numerous factors at each station. The type that is used in this case is a hierarchical neural network which is modeled on the information processing of the brain and calculates output information by processing input information hierarchically as shown in Figure 15.

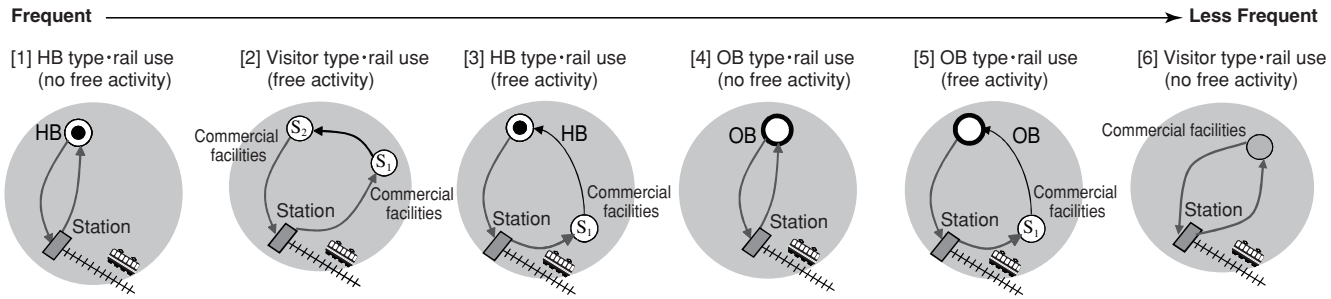

Fig. 13 Result of travel behaviour pattern categorization for senior citizens

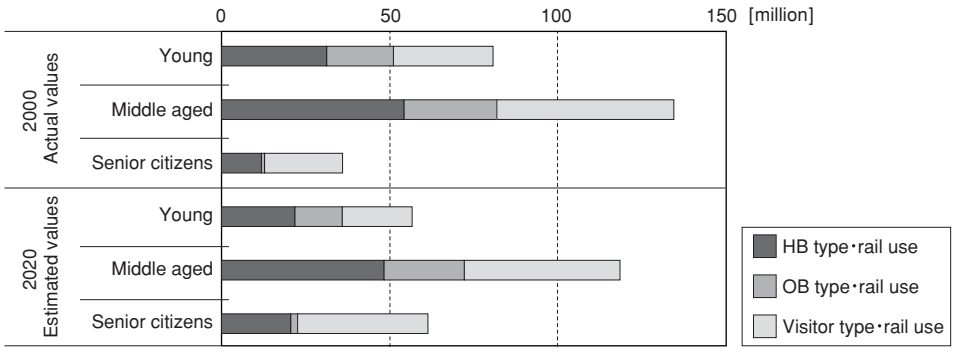

Fig. 14 Estimation results of future travel behaviour patterns by age group

Also, 11 factors that are thought to have a bearing on travel behaviour of each age group were selected as input variables from the attribute data of the area around the station mentioned earlier. The composition ratio of the HB and OB type travel behaviour patterns for each age group was used as the output layer. The quantitative data of the factors in the Railway Station Database were each converted into numerical values between the maximum and the minimum values of 0 and 1 to be used as supervised data for the NN model. The supervised data, therefore, is comprised of standardized groups of numerical values. The HB, OB and visiting type ratios add up to 100%. Therefore, the composition ratio for the visiting type pattern was calculated from the estimation results for the HB and OB types.

Furthermore, NN parameter settings were calculated using the usual back propagation method with the Railway Station Database above as the supervised data. Any number of neurons in the intermediary layer can be assigned in modelling. In this study, several settings were tried for the number of neurons in the intermediary layer and the layer with 12 neuron with the least amount of estimation error was determined. In this model, there are 6 neurons in the output layer, designed to provide for numerous information processing channels.

A travel behaviour pattern composition estimation model using NN was identified by installing the network parameters that were calculated.

The estimation result obtained from the NN model created during this study is shown in Table 3. A comparison is made with the result from a logit model created using the same explanatory factors. Using the NN model, which can model the complex relationships of the factors, and comparing it with the logit model allows for high-precision estimation. In particular, it was found that highly precise estimation results could be obtained for the composition ratio of the OB type travel behaviour pattern.

Travel behaviour patterns tend to emerge as a consequence of varied and complex correlations of individual factors. Therefore, it is difficult to explicate the direct

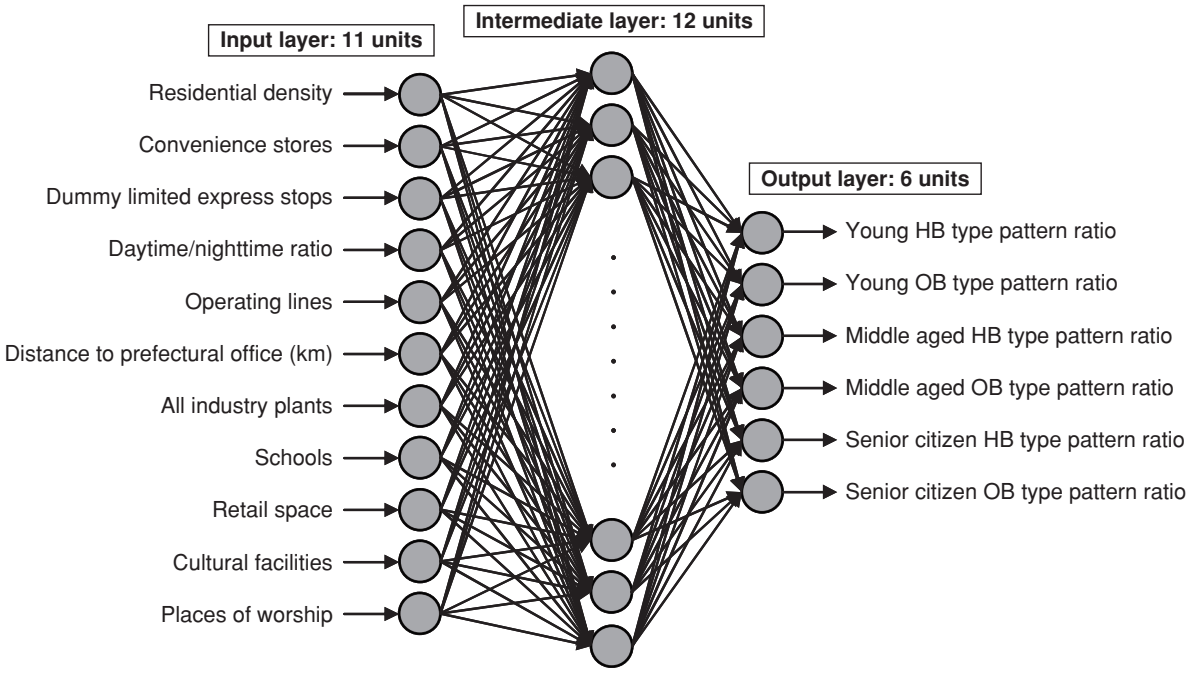

Fig. 15 Structure of the travel behaviour pattern ratio estimation NN model

Table 3 Estimation result of the travel behaviour pattern ratio using the NN model

RMSE	Young		Middle aged		Senior citizens	
	HB	OB	HB	OB	HB	OB
Logit model	0.169	0.159	0.164	0.141	0.179	0.103
NN model	0.123	0.125	0.105	0.104	0.134	0.087

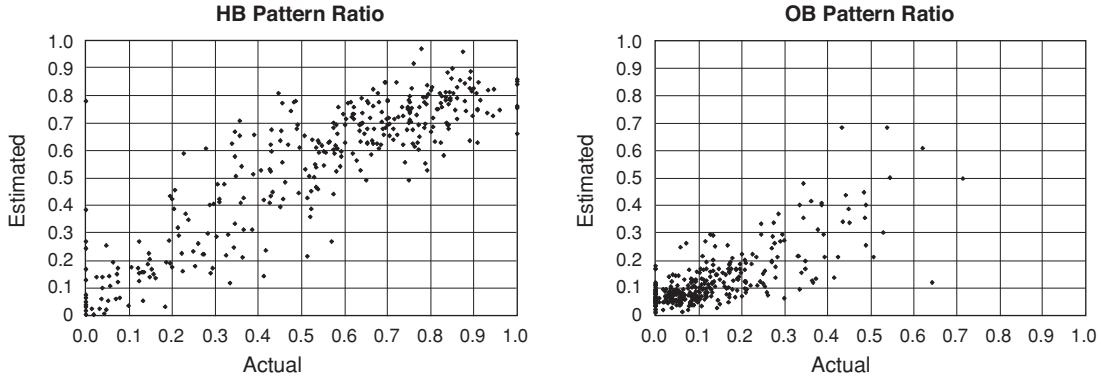

Fig. 16 Estimation result for the travel behaviour pattern ratios of senior citizens

causal relationship. However, the NN model is believed to be effective in modeling this complexity and in providing precise estimation.

The overall estimation results were verified in Table 3. As an example of the estimation result for the respective stations, Figure 16 shows the actual and estimation values for the HB and OB types in the senior citizen age group. The chart shows that a relatively sound estimation of travel behaviour patterns for each station can be obtained.

4. ESTIMATION OF TRAVEL BEHAVIOUR PATTERNS ACCOMPANYING DEVELOPMENT OF AREA AROUND RAILWAY STATION

In this chapter, the age group-specific travel behaviour pattern estimation models that are described thus far are applied to realistic development problems in the areas around railway stations. The impact of commercial development relating to urban railway stations on transport behaviour is calculated quantitatively to examine the effectiveness of urban policies.

This study looks at the Hankyu Nishinomiya Gardens shopping centre which was built with the intention of becoming a new centre in the Keihanshin metropolitan areas. This large scale facility, which opened on 26 November 2008, is a shopping centre designed to cover a basic trading area of 10 km (population of approx. 1,700,000) around the railway station.

Previous travel behaviour patterns at Hankyu Nishinomiya-Kitaguchi Station based on the Railway Station Database mentioned earlier are as shown in Figure 17. According to this chart, the distinctive characteristics in the travel behaviour patterns of 2000 were that there were more OB type patterns than HB type patterns among young and middle aged groups, and that there were numerous observations of travel behaviour with visiting type free activities among young and senior-citizen age groups. In other words, the station has long been a highly appealing destination to visit within the Keihanshin metropolitan areas.

Here, the number of passengers at the station is estimated using the regression analysis model described in earlier chapters and the result is then used to estimate travel behaviour patterns for each age group using the NN model. The explanatory variables for these models is set at the levels at the opening of Hankyu Gardens. The setting factors are: “Day/night ratio”, “All Industry Plants” and “Retail Space".

1) Day/night ratio: The nighttime population before

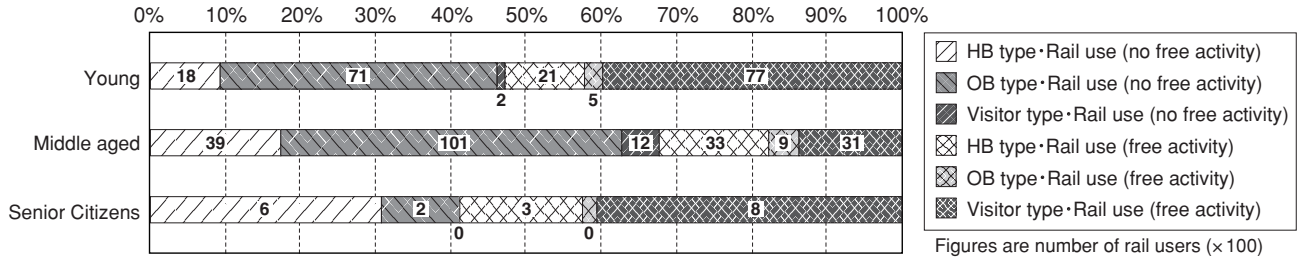

Fig. 17 Travel behaviour pattern composition by age group of Hankyu Nishinomiya-Kitaguchi Station users

opening was 12,213, the daytime population was 11,309 and the day/night ratio was calculated at 0.926. The number of visitors to the newly opened Hankyu Gardens is expected to be approximately 20 million a year, an average of 4,795 visitors each day. Therefore, the daytime population after opening will be the sum of the daytime population before opening of 11,309 and the expected number of visitors after opening of 54,795, which comes to a total of around 66,104. Accordingly, the day/night ratio after opening is assumed at 5.413 (=66,104/12,213).

2) All industry plants: The number of shops that opened at Hankyu Nishinomiya Gardens is 268. Added to the 732 industrial establishments that were present before opening, the number of establishments is assumed at 1,000.
3) Retail space: The total floor area of the newly constructed facilities at Hankyu Nishinomiya Gardens is 247,000 m^2. Adding this to the total sales floor area prior to constructions of 16,734 m^2, the new total was assumed at 263,734 m^2.

The number of passengers using the station after the opening of the complex was estimated using the assuming conditions above by means of regression analysis. In this case, the growth rate after opening was calculated from the regression analysis result so as to eliminate the effects of regression error. This value was multiplied by the actual value to obtain the estimation result after opening. Table 4 shows the calculation results for these. According to these results, the growth rate of passenger numbers at the station is largest for the middle aged group followed by the young and senior-citizen groups in that order. This is attributed to the fact the construction of a large scale shopping centre is accompanied by an expansion in commercial scale and an increase in business opportunities. The total of the number of passengers at the station for each age group is calculated at approximately 100,000. Although a definite value for the number of passengers is yet to be reported, a comparable figure has been observed after about a month into operations.

Next, the NN model was used to estimate the travel behaviour changes in Nishinomiya-Kitaguchi station users. The assuming conditions after the opening of the shopping centre were used on the model to estimate the composition ratios of travel behaviour patterns for respective age groups. According to Figure 18, the ratio of the OB type travel behaviour pattern is on the increase

Table 4 Estimation result for number of passengers subsequent to redevelopment of the area in front of Hankyu Nishinomiya-Kitaguchi station

	Actual figures before opening	Estimate			Estimate after opening
		Before	After	Increase	
Young	24,314	14,666	23,593	1.609	39,114
Middle aged	27,642	17,948	42,876	2.389	66,033
Senior citizens	3,442	2,095	2,425	1.157	3,984
Total	55,398	34,710	68,894	1.985	109,958
	A	*B*	*C*	*D=C/B*	*E=A*D*

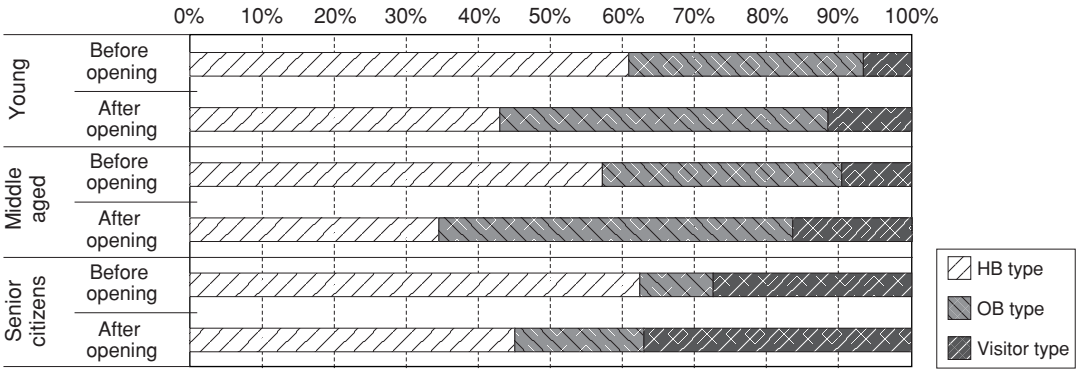

Fig. 18 Estimation result for travel behaviour pattern composition by age group of Hankyu Nishinomiya-Kitaguchi Station users

among the young and middle aged groups. On the other hand, OB and visiting type travel behaviour patterns are increasing among senior citizens.

In the travel behaviour pattern composition ratio, the visiting type pattern among senior citizens eventually arrives at around 40%. This reflects a travel behaviour in which visits are made from other regions for shopping and recreational purposes and is indicative of fundamental effects from large scale commercial development. Meanwhile, since a large scale shopping centre holds promise of expansion in related businesses, these factors are believed to have brought about an increase in the OB type travel behaviour pattern among middle aged and young age groups.

This paper considered a large scale shopping centre as an example of development around a railway station. In carrying out individual commercial development, however, it is necessary to discuss the development concept as well as detailed differences in commercial formats that reflect that concept. Particularly in the case of limited commercial development, it is necessary to implement individualized analysis and it may be difficult to utilize the basic commercial statistical classification used in this study for deliberations. Deliberation would also be required with respect to database organization.

However, as mentioned above, a close correlation does exist between commercial development in areas around railway stations and changes in traffic flows of respective age groups and the study has provided much insight into comprehensive development of public transportation and urban functions.

5. CONCLUSION

This study analyzed travel behaviour patterns at areas around railway stations in the Keihanshin metropolitan areas from the perspective of public transportation and age group-specific travel demand. It examined, in specific terms, how the composition of travel behaviour patterns by age group pertaining to town development was related to local revitalization. The results of this study can be summarized as follows:

1) The amount of activity by senior citizens relative to that of young and middle aged groups is expected to increase in an aging society with falling birthrates. Factors affecting differences in passenger numbers for each age group in areas around railway stations were extracted by means of regression analysis and an estimation model was created. The characteristics of rail use behaviour were sorted by age group and the railway usage patterns of senior citizens were found to be distinctive. As a result, it became clear that a demand estimation of urban railway use by age group was meaningful and that specific railway development status was relevant to promoting railway use.
2) An analysis was made of travel behaviour patterns with free activities (shopping, recreation) by age group around railway stations. 6 types of travel behaviour patterns were defined based on basic travel behaviours. As a result, it was found that travel behaviour patterns among the young and middle aged groups mainly consisted of commuting and business activities while that registered by senior citizens consisted of visiting type free activities. Furthermore, an NN model was used to express the correlation between these factors so that the travel behaviour patterns by age group at each station can be estimated.
3) In order to make a realistic review of rail transportation and town development, the estimation models mentioned above were used to estimate the travel behaviour patterns expected at the opening of a large scale shopping centre. It was evident that large scale commercial development had various effects on travel behaviour of the respective age groups. In particular, it was found that such a development increased visiting type travel behaviours among senior citizens but also induced growth in OB type travel behaviours in the young and middle aged groups. This showed that it is possible to examine effects of town planning by age group and to study them from the perspective of changes in urban activities.

This study examined differences in railway users of respective age groups from their travel behaviour patterns. In particular, it became evident that there was a meaningful connection between railway usage patterns mainly relating to free activities and development of areas around railway stations. In view of the results of this study, we can conclude that it is extremely important to give careful thought to the travel behaviour of respective age groups in future railway station and town development projects (local revitalization) and in promoting the use of urban railway. Subjects for future consideration include: 1) Improvement of precision in quantitative estimation of user age group composition at respective railway stations and demand changes relating to railway use; 2) Identification of specific effects on revitalization of the area around stations (town) and travel behaviour patterns by organizing data on actual case examples; 3) More detailed identification of differences in travel behaviour

patterns among various age groups (for instance, including studies on the latter-stage elderly sector), etc.

REFERENCES

1. Kitamura, R. Town Development Using Railway. Gakugei Shuppansha. (2004).
2. Institute of Urban Transport, Kansai Railway Association. Railway Network in the Kinki Region and Transitions along Railroads. Research Series No. 29. (2004).
3. National Institute of Population and Social Security Research. Population Projections by Prefecture for 2005-2035 (May 2007). Health & Welfare Statistics Association.
4. Hankyu Corporation. HANDBOOK HANKYU 2008. (2007)
5. Akiyama, T., Tanaka, N. and Okushima, M. Discussion for Potential of Railway Station in Kansai Urban Region. "Infrastructure Planning Review" 24: pp. 207-216. (2007).
6. Akiyama, T., Okushima, M. and Kitamura, R. The Basic Analysis of Railway Travel and Shopping with the Trip Survey Database. "Transportation Studies" 48: pp. 169-178. (2004).
7. Institute of Urban Transport, Kansai Railway Association. Empirical Research on Railway Stations and Towns. Research Series No. 34. (2008).
8. Akiyama, T., Okushima, M. and Kitamura, R. The Empirical Analysis of the Railway Station and Town Management Concerning with Urban Activities. "Transportation Studies" 51: pp. 99-108. (2008).
9. Okushima, M. Akiyama, T., and Kitamura, R. The Analysis of the Railway Station and Town Management with a Focus on Travel Behaviour of the Elderly. "Transportation Studies" 52: pp. 71-80. (2009).

ACKNOWLEDGEMENTS

In conducting this study, the authors made use of the Railway Station Database compiled by the Committee for Railway Station and Urban Studies, Institute of Urban Transport, Kansai Railway Association. We would like to extend our thanks to the institute for its cooperation in allowing us to use the data. We would also like to express our appreciation to the Keihanshin Metropolitan Area Comprehensive Transport Planning Council for allowing us to use the Keihanshin metropolitan area person trip survey results.

Lastly, this study is the product of ongoing collaborative research with Professor Ryuichi Kitamura of Kyoto University Graduate School of Engineering. Countless comments and suggestions were offered by the professor in compiling the contents of this report. We would like to express our cordial gratitude to his contributions and, in receiving news of his recent death, offer our sincerest prayers for the repose of his soul.